REMARKS/ARGUMENTS

Favorable reconsideration of this application as presently amended and in light of the following discussion is respectfully requested.

Claims 4, 7 and 16-25 are presently active in this case, Claims 1-3, 5-6 and 8-15 canceled, and Claims 21-25 added by way of the present amendment.

In the outstanding Office Action, Claims 16-20 were withdrawn from consideration as directed to a non-elected invention; Claims 1-3, 8-10 and 15 were rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 6,459,126 to Mogami; Claims 4, 7, 11 and 14 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Mogami; and Claims 5-6 and 12-13 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Mogami in view of U.S. Patent No. 6,511,539 to Raaijmakers.

Turning now to the merits, Applicants' invention is directed to a method of forming an oxynitride film. As discussed with respect to Figures 1 and 2 in the Background section of Applicants' specification, heat treatment of a high-k gate insulating film can have the undesirable effect of causing a base oxide 12 thickness to increase.[1] This can be prevented by forming a nitride film 12a as a barrier between the base oxide 12 and the high-k film 13.[2] However, forming a nitride film 12a can reduce productivity for the semiconductor device, and poor nitrogen concentration in a thickness direction of the film can cause nitrogen concentrations at an interface of the oxide 12 that result in operational problems for the device.[3] According to one feature of Applicants' disclosed invention, a nitrogen-containing film can be formed by varying a mixture ratio of oxygen-containing gas and nitrogen-containing gas in order to form an oxynitride film in one step and with accurate control of nitrogen in a thickness direction of the film growth. In order to expedite issuance of a patent

[1] Applicants' specification at p. 3, line 18-p.4, line 10.
[2] Applicants' specification at p. 4, lines 11-26.
[3] Applicants' specification at p. 5, lines 1-10.

in this case, Applicants have amended Claim 4 to be in independent form and to clarify this feature of the invention.

Specifically, Claim 4 as amended recites a method for forming an insulating film on a silicon-containing substrate to be processed, the method including forming a gas mixture by mixing a nitrogen-containing gas and an oxygen containing gas, the nitrogen containing gas being a nitrogen gas or a nitrogen compound gas and the oxygen containing gas being an oxygen gas or an oxygen compound gas. The gas mixture is excited using a high frequency plasma to produce nitrogen radicals and oxygen radicals, and these radicals are supplied to the surface of the substrate to create an insulating film containing nitrogen. Also recited is that when the gas mixture is formed, the gas mixture ratio between the oxygen containing gas and the nitrogen containing gas varies with time. New Claims 21 and 25 similarly require varying the oxygen-containing gas and nitrogen-containing gas mixture by reciting that at least one of the oxygen-containing gas and the nitrogen-containing gas is provided intermittently. These features are supported at least by page 24, line 1 - page 29, line 7 and Figures 11-15 of Applicants' specification as originally filed.

As discussed in Applicants' specification, in the actual semiconductor device, when the device characteristics are taken into account, the nitrogen concentration may preferably be lower near the silicon (Si) substrate, (for example, during the first half of the oxynitriding process), to form a smooth interface between the silicon substrate and the oxynitride film.[4] On the other hand, it may be preferable to keep the nitrogen concentration higher near the high-k dielectric film, (for example, during the second half of the oxynitriding process), to prevent mutual diffusion between the metal in the dielectric film and the silicon.[5]

[4] Applicants' specification at page 27, lines 16-21.
[5] Applicants' specification at page 27, lines 22-26.

Applicants' claimed invention provides this capability by use of a gas mixture ratio between the oxygen containing gas and the nitrogen containing gas that varies with time.

In contrast, Mogami et al. discloses a semiconductor device including a MIS transistor having a gate insulator made of silicon oxynitride. The Office Action cites Fig. 10 of Magami as disclosing the varying limitation of original Claim 4. this figure plots three radical processes, but only the second radical process teaches that oxygen gas and a nitrogen gas are simultaneously introduced into a chamber in the ***ratio of 1:1*** and each about in a partial pressure of 1×10^{-1} Pa (see Col. 6, lines 18 to 26). However, Mogami dose not disclose, suggest or imply specifically varying the mixture ratio between the oxygen gas and the nitrogen gas with time in order to form an oxynitride film with varying nitrogen concentration gradient along the direction of the thickness of the oxynitride film. To the extent that the Office Action considers this variation in ratio to be inherent due to the change in nitrogen concentration with depth, Applicants disagree. The remaining two radical processes in Figure 10 do not even provide the nitrogen and oxygen gases simultaneously, but still show nitrogen changing with depth. This demonstrates that the change in nitrogen concentration is not caused by a ratio change in oxygen to nitrogen gas. Therefore, the varying ratio limitation is not inherent in Magami and it would not have been obvious to a person of ordinary skill in the art to vary the gas mixture ratio in order to form the oxynitride film with varying nitrogen concentration gradient along the direction of the thickness of the oxynitride film.

Therefore independent Claims 4, 21 and 24 patentably define over the cited references. As Claims 7 and 22-24 depend from one of the independent claims, Claims 7 and 22-24 also patentably define over the cited references. Nevertheless, Claim 7 recites that the high frequency plasma is produced by exciting the nitrogen gas and the oxygen gas at a frequency of 400 kHz-500 kHz. Since the nitrogen ions and the oxygen ions do not

contribute to the formation of an oxynitride film, it is preferable that the amount of the nitrogen ions and the oxygen ions be kept small.[6] Further, in order to minimize damages that might be incurred on the substrate to be processed, the number of the nitrogen ions and the oxygen ions is preferred to be small. When a microwave is used to generate plasma, ionization of nitrogen molecules and oxygen molecules is accelerated, thereby forming a plenty of nitrogen ions and oxygen ions. On the other hand, when a high frequency wave of 500kHz or less is used, formation of nitrogen ions and oxygen ions is greatly reduced.[7]

Further, when executing a plasma excitation with a microwave, a high vacuum level (low pressure) of $1.33 \times 10^{-1} \sim 1.33 \times 10^{-4}$ Pa ($10^{-3} \sim 10^{-6}$ Torr) is required as shown in Fig. 6; whereas a relatively high pressure of 1.33 Pa ~ 13.3 kPa (0.01 ~ 100 Torr) is sufficient in case of a high frequency plasma excitation. Therefore, it is preferable that the high frequency plasma is produced by exciting the nitrogen gas and the oxygen gas at a frequency of 400 kHz-500 kHz.

However, Mogami fails to disclose, suggest or imply that the high frequency plasma is produced by exciting the nitrogen gas and the oxygen gas at a frequency of 400 kHz-500 kHz. This provides an additional basis for patentability of Claim 7 over the cited references.

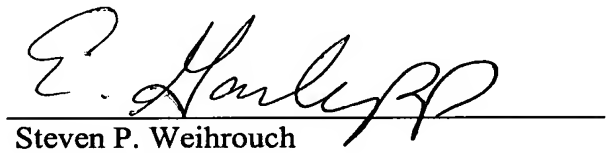
Consequently, in view of the present amendment, no further issues are believed to be outstanding in the present application. The present application is believed to be in condition for formal allowance. An early and favorable action is therefore respectfully requested. If

[6] Applicants' specification at page 18, lines 8-21.
[7] Applicants' specification at page 17, lines 5-18.

the Examiner feels that a personal discussion might be helpful in advancing this case to allowance, the Examiner is invited to telephone the undersigned.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.



Steven P. Weihrouch
Attorney of Record
Registration No. 32,829

Edwin D. Garlepp
Registration No. 45,330

Customer Number
22850

Tel: (703) 413-3000
Fax: (703) 413 -2220
(OSMMN 03/06)
I:\ATTY\EDG\267410US-AM.DOC